White Paper
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Best Practices in Math and Reading for Elementary Students
A Research Review
Executive Summary

The Problem
Production of this report began with a concern about elementary student scores in reading and math in Lake County, Indiana. On the 2011 National Assessment of Educational Progress, taken by fourth graders, scale scores (a calculation of a total score on a test), for students in Indiana were 221 for reading and 244 for math. The national average in reading was 220 and 240 for math. In reading, 16 states scored higher than Indiana with 15 scoring below. In math, the scores were 6 above and 28 below. These scores suggest that students in Indiana may not be doing as badly as first thought, however, scores on the ISTEP test suggest differently, at least for some population.

Percent of students passing ISTEP

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<tr>
<th>Grade</th>
<th>ELA</th>
<th>Math</th>
<th>Range Girls ELA*</th>
<th>Range Boys ELA*</th>
<th>Range All Schools in ELA*</th>
<th>Range Girl Math*</th>
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<td>3</td>
<td>83</td>
<td>78</td>
<td>96.7-76.7</td>
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<td>82</td>
<td>79</td>
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<td>86</td>
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<td>91.2-48</td>
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<td>92.9-44.6</td>
<td>90.2-43.8</td>
<td>91.7-44.2</td>
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Note: * Range denotes the highest score passing and the lowest score for all schools
ELA= English/Language Arts

An overall analysis of this data suggests that the range of scores is more significant than the overall scores. It is clear that in some schools children are performing quite well and in others not so well. This may be explained by the variance in socioeconomic status in the county. Also, the lowest scores seem to be related to grade level. An explanation for this might be current initiatives schools in Lake County have undertaken. In an attempt to raise student scores schools in Lake County have increased use of Indiana’s Response to Instruction, the use of literacy coaches, the use of co-teaching models and differentiated instruction. This paper is meant to aid educators and others in defining instructional approaches which research suggests have been helpful in increasing student scores.

The Review
A review of the literature was conducted using the following data bases: Education Full Text (EBSCO)(H.W. Wilson)(XML), ERIC (EBSCO). MasterFILE Premier (EBSCO), OmniFile Full Text Mega (EBSCO)(H.W. Wilson)(XML), Professional Development (EBSCO), SpringerLink (MetaPress), and Wiley Online Library. Included in the review were studies on whole class and small group instruction as they related to elementary students. Not included in the review was information on specific textbooks or the use of technology in general (though some specific studies using technology were included because it was combined with other topics). A review of specific textbooks was not included. This was not done because instructional research is generally conducted on each skill set defined in the text. Technology was not included because,
at the current time, there is little research to suggest that the use of it has a large effect on reading or math learning in terms of overall curricular.

An Analysis
An overall analysis from the review suggests that:

- In reading students need to develop very specific skills in a very specific order to achieve the overall goal of comprehension
- Explicit instruction in the areas of phonemic awareness and phonics appears to benefit students the most
- Fluency and vocabulary skills are best achieved by specific types of instruction
- Research supports that comprehension skills and strategies are best taught in cooperative groups
- In math students need to be fluent in math computation skills and the use of problem solving strategies in order to be successful in higher order skills
- Fluency in math computation can be achieved by explicit instruction
- Problem solving is more successful when taught in cooperative groups
- There are similarities in cognitive and metacognitive thinking between reading comprehension and math problem solving
**Phonemic Awareness**

Phonemic awareness is the ability to hear and manipulate sounds in their smallest unit (phonemes) in spoken words and understand that words are made of a series of speech sounds. Although there is continued controversy, phonemic awareness has been pinpointed as a predictor of early reading success (NICHD, 2000). Adams (1990) and Stanovich (1986) suggest that a child's level of phonemic awareness on entering school is held to be the strongest single determinant of the success or failure that she or he will experience in learning to read. The report of the Committee for the Prevention of Reading Difficulties in Young Children states that the development of phonemic awareness should be a priority goal in kindergarten classes (Snow, Burns, & Griffin, 1998). Currently researchers are in disagreement as to whether it is best to teach phonemic awareness through a whole language teaching (teaching in a contextual or authentic framework) or explicit direct instruction of skills. There are multiple studies to support each position.

The whole language proponents suggest that children learn best using authentic text with support for skill development. In studies conducted by Ribowsky (1985) and Kasten and Clarke (1989) with kindergarteners, there was a significant difference for students who received instruction in a whole language approach, as opposed to the students that received more explicit skills directed instruction. These differences were noted in all measures of reading growth and achievement, including tests of letter recognition, letter/sound knowledge, and scores on the Metropolitan Readiness tests (including beginning consonant sounds, letter/sound correspondences). In a longitudinal study conducted by Manning, Manning and Long (1989) with inner-city children, including students from kindergarten through grade two, students in the whole language classroom did significantly better on the Stanford Achievement Test’s subtests on word parts. In two studies that looked at how children used specific types of strategies to solve unknown words (Stice & Bertrand, 1990; Cunningham, 1990) students that experienced the whole language approach were able to describe more strategies to use and there was a generally higher transfer of reading skills.

Conversely, research indicates that, without direct instructional support, phonemic awareness eludes roughly 25 percent of middle-class first graders, and substantially more of those who come from less literacy-rich backgrounds (Adams, 1990). In a study conducted by Blachman, Ball, Black and Tangel (1994) with kindergarteners in low-income inner-city classrooms, the students in the experimental group (taught explicitly) significantly outperformed those in control on phoneme segmentation, letter name, and letter sound knowledge. Further, in a long term study conducted by Byrne & Fielding-Barnsley (1991, 1993, and 1995) students were taught about phonemic structure in an explicit manner. At the end of kindergarten, these students performed significantly better on measures of phonemic awareness, word identification, decoding, and spelling. Compared to a control condition, the trained children were superior in nonword reading 2 and 3 yrs later and in reading comprehension 3 years later.

Given the controversy over instruction, there are some things that researchers do agree are necessary for children to begin the reading “journey” successfully. These are: that phonemic awareness facilitates learning to read, that worksheets and mindless drill are not the best means of developing phonemic awareness and phonics knowledge (Cunningham, 1990), that children should be given explicit and direct help in developing phonemic awareness, that for
the majority of children direct teaching does not have to be intensive and systematic, and that about 15-20% of our children will need additional help in developing phonemic awareness. (Lyon, 1996). Perhaps the most helpful way to look at the teaching of phonemic awareness is that instruction be based on individual need.

Several studies that produced significant results in topic specific instruction are:

(1) specific teaching of sound blending (Farmer, Nixon, White, 2001), (2) letter-name and letter-sound instruction (Ball and Blachman, 1991), (3) listening games, rhyme, sentence segmentation (Lie, 1991; Byrne & Fielding-Barnsley, 1991, 1993, 1995; Lunberg, Frost, and Petersen, 1988) and syllable segmentation (Lunberg, Frost, and Petersen, 1988), (4) segmentation activities and letter-name and letter-sound training (Gaskins, et al 1997). Further, the idea of scaffolding skills (Vygotsky 1978), the teaching of small segments with consistent and repeated instruction, until mastery is obtained, is supported in terms of phonemic awareness training (McGee, L., & Ukrainetz, T. 2009). Once children have successfully mastered phonemic awareness the teaching of phonics is appropriate.

**Phonics**

Phonics is the ability to identify that there is a relationship between the sounds of spoken language, and the letters of written language. More specifically letter sound correspondence (a – apple-ah). Wagener and Torgeson (1987) suggested that when a child can understand the relationship between sounds and the corresponding letters, the child can then make sense of the letter patterns necessary for reading. In general it helps children decode unknown words. Although instruction type is highly controversial in education, several studies have indicated that systematic phonics instruction facilitates learning to read (NICHD, 2000). Some methods of phonics instruction support teaching in a whole language approach and other are more explicit skill directed. Some of these are: (1) embedded (used with whole language for ‘teachable moments’) and analytic (children are given the whole word and then taught how to analyze parts of the word, this is often a method of teaching in whole language also), these are considered more whole language instruction and (2) synthetic (children are explicitly taught how to make letters into sounds and blend the sounds to form words with exposure to unknown words so that skills are transferred, as well as, the ‘rules’ of language) and analogy phonics (children or taught using word families (at, it, ot ), which are considered more explicit. Like phonemic awareness, there continues to be a debate as to whether explicit or implicit instruction of phonics helps children be successful in later reading tasks. Stanovich (1994) stated that his own research convinced him, after 20 years, “That direct instruction in alphabetic coding facilitates early reading acquisition is one of the most well established conclusions in all of behavioral science” (p. 285).

However, there are several studies that suggest implicit instruction using authentic text may have some successful outcomes. In a study conducted by Manning and Kamii (2000) students received either explicit or implicit approaches which emphasized reading and writing in real-life practical contexts. These students were kindergarteners from an urban school. The children who received implicit instruction, made greater more uniform progress through the year in reading and writing tests. Further, Shapiro and Solity (2008), examined what the effects of integrating explicit phonics training into a whole language approach class might be. They used mixed-ability reading lessons to determine the impact this might have on children with poor phonological awareness, as well as normally developing readers. Students were an average of 4
years, 8 months at the inception of the program and the study was conducted over a three year period with the control group receiving regular instruction. Follow-up assessment was made after the first and third years. The instruction significantly impacted reading performance (segmentation, rhyming and synthesis) for normally developing readers and those with poor phonological awareness. General reading scores increased 33% faster and the incidence of reading difficulties was 20% in comparison groups as opposed to 5% in intervention groups. Implications of this study clearly are that mixed ability grouping in classrooms may have a significant effect on learning for all.

Again, consideration of the contrasting viewpoint also provides us with some strong research. In a study conducted by Bowey and Christian (2005), two groups of second graders were instructed in very specific phonic approaches, a third group received implicit training involving authentic text. Students in the implicit phonics group consistently performed more poorly than the other group in reading and spelling words. Further, analytic (implicit) and synthetic (explicit) computer based phonics instruction were compared in three studies. In studies conducted with computer programs with implicit or explicit instruction, Comasky, Savage & Abrami (2009) and Savage, Abrami ,Hipps & Wade (2009) , found that each program affected different skill sets. These studies were conducted with a group of first graders and disadvantaged urban kindergarteners. The implicit approach affected scores on listening comprehension, reading comprehension, and shared rime words (bat,cat,sat) whereas those in the explicit groups scored significantly better in areas of phonological awareness, fluency blending consonant vowel, vowel consonant words, and final consonants. De Graaff, Bosman, Hasselman& Vanderloot (2009) conducted a study with 93 kindergarteners who were randomly exposed to either an explicit or implicit computer program. Children that were instructed using the explicit program scored significantly better on measures of phonemic awareness, spelling and reading. Again, it would seem prudent when planning instruction to identify the individual needs of students. Fluency development builds upon phonemic awareness and phonics skills.

**Fluency**

Fluency is the ability to read accurately, quickly and with expression (prosody). Because we only have a certain amount of cognitive resources, if a child is functioning at the letter or word sounding level, they are not reading fluently, therefore cognitive resources needed for comprehension are not available. Speece and Ritchey (2005), suggest that Oral reading fluency (ORF) is a preliminary and imperative step of reading comprehension. Hasbrouck et al. (1999) suggest that students who are not fluent often read without expression and often ignore punctuation so that the task becomes boring and as result, non-fluent students read less and fall further behind their peers. Considering the idea of prosody, several studies have included significantly different results in comprehension scores for students that do/don’t read with expression (Daane et al., 2005; Pinnell et al., 1995; Rasinski, Rikli, & Johnston, 2009). Two accepted views of fluency instruction are wide reading and repeated reading. Wide reading is what occurs in most classrooms. In this type of instruction children read a text, there is some type of discussion and instruction related to the text, and then another story is read. Repeated reading is characterized by a child rereading text multiple times to achieve fluency. Repeated reading allows the student to reread so that the text is ultimately comprehended rather than just “word read”.

A study conducted by Olson (2011), involved identifying weaker and stronger readers and two types of tutoring groups. In both groups weaker and stronger readers were paired and the weaker readers were the tutors with the stronger readers being tutees. The difference in the groups was that in one group only the tutors received instruction about the readings, whereas, in the other group, both the tutors and tutees received the instruction. The participants were eighty 2nd grade students from two lower performing urban, public schools. The tutors in the experimental group increased reading accuracy from 86.9% to 90.5% and reading rate from 66.4 words correct per minute (WCPM) to 73.7. The comparison tutors accuracy WCPM actually decreased. The results of this study suggest that motivation and the internal perception of one’s reading abilities may play a significant role in success, especially for lower performing students.

Repeated reading has been researched extensively as an intervention for helping children who struggle with fluency which ultimately affects their comprehension. Repeated readings have been shown to be the most effective practice for developing fluency (Dowhower, 1994; Samuels, 1979). In addition, research suggests that as students engage in repeated readings, not only do they improve their ability to read the text that is reread, but more important, improve in overall reading achievement (Rasinski & Hoffman, 2003; Stahl & Kuhn, 2002). Further, scaffolding of skills is a generally accepted manner of repeated reading. In this approach the reading is modeled by a more fluent reader (this can be in the form of a teacher, peer or audiotape) (Cole & Lionetti, 2004; Rasinski, 1990), then the student reads the text back to the partner with prompting and correction (Pearson & Gallagher, 1983; Rasinski, 2003). Activities often supported in the classroom for repeated reading are poetry reading (Rasinski, 2000), choral reading (Rasinski, 2004) and readers theatre (Martinez, Roser, and Strecker, 1998). In a study conducted by Begany, Krouse, Ross & Mitchell (2009) with second graders, three different types of intervention were used: repeated reading, listening passage preview, and listening only. Repeated reading followed by listening passage preview was seen to be most effective in an increase of words correct per minute or speed. In another study with second graders, Conderman and Stobel (2008), used repeated reading for 5 minutes per day throughout the school year. There were more gains on fluency tests in areas of accuracy and speed for the group with the intervention than comparisons and that growth was still evident a year after. In conclusion, the third study ties the prior discussion together in looking at additive effects of feedback and reward on the repeated reading model. Chafouleas, Martens, Dobson, Weinstein, Gardner (2009), conducted a study with 3 elementary students to collect data on whether adding feedback on performance, and/or a reward for good work would have an effect on fluency scores. The student with the highest fluency rate at the beginning of the study increased on fluency measures the most with just repeated reading instruction alone. The students who had the lowest rate performed best with the addition of feedback alone or feedback and reward. Implications from this study suggest that students that struggle the most might benefit from an increase of external reinforcement in addition to an intervention. Develop of skills suggest that vocabulary plays an important role in the building of skills, with the ultimate goal of successful comprehension.

Vocabulary

Biemiller (2005) and Hart & Risley (1995) suggest that a child’s socio-economic status is a critical correlate of vocabulary knowledge. A concern then would be that, according to Biemiller and Boote (2006), “Current reading instruction is apparently premised on the view that children can build the vocabulary they need after learning to read (decode) fluently, as little or no vocabulary instruction occurs during the primary grades” (p.44). Further, two conflicting views of how to teach vocabulary, are whether it should be taught in context or if explicit instruction in
morphology (including base word derivative, suffixes, and prefixes) should occur. The contextual approach, often termed the shallow but wide approach, includes teaching of a few words a day with the support of a story. Studies by (Biemiller & Boote, 2006 and Se’ne’chal, 1997) concluded that introducing brief explanations while reading significantly increased comprehension. However, they also suggest that these brief explanations should be followed up with more exposure to the specific words. The second view, often termed rich but narrow approach, suggests that varied and multiple experiences with words have an effect on comprehension (Mezynski, 1983; Stahl & Fairbanks, 1986). A common recommendation for vocabulary instruction is “word study” which is explicit teaching of morphology (Blachowicz, Fisher, & Ogle 2006; Graves & Watts-Taffe, 2002; National Reading Panel, 2000).

In a study conducted by Nelson (2007), third and fifth grade students received either a contextually-based vocabulary approach, or the typical language arts instruction. Students in the contextually-based group had a significant increase in vocabulary skills( data supports that this increase was more prevalent for students with low to normal baseline data) and significant increases were noted in comprehension scores (except for the students that were high achieving fifth grade class). Three instructional conditions were examined by Hawkins and Musti-Rao (2010) in a study with fourth grade general education students. The three conditions were silent reading, listening preview, and listening and vocabulary previewing. Significantly more comprehension questions were answered correctly in both previewing conditions than silent reading. Further students in the combined vocabulary conditions answered significantly more comprehension questions correct and performed significantly better on the vocabulary matching task than either of the other groups. Implications for this study suggest that silent reading time (often used in classrooms), can be paired with other instruction to increase very specific types of learning.

Explicit teaching of morphology in terms of whole class has been researched fairly extensively. In studies conducted by Nunes, Bryant, and Olson (2003) and Nunes and Bryant (2006), explicit instruction in morphology was noted to have a significant effect on word reading and spelling. White, Sowell, and Yanagihara (1989) and Nicol, Graves and Slater (1984) instructed high-ability third graders and fourth, fifth and sixth graders on prefixes respectively. Students in the experimental group outperformed controls on tests of root and prefix meanings and on transfer tests of unfamiliar prefixed words and immediate and delayed transfer of word knowledge. Finally, Wysocki and Jenkins (1987), conducted an experiment in which fourth-, sixth-, and eighth-grade students were provided instruction in the definitions of low-frequency words in isolation and sentence contexts. Results identify significant gains in word knowledge for words that were explicitly taught and paired with context. The effectiveness of an extended approach (both explicit and contextual instruction) to vocabulary instruction has been supported in a number of research studies (Beck&McKeown, 2007; Coyne, McCoach, & Kapp, 2007; Coyne, McCoach, Loftus, Zipoli, & Kapp, 2009). This combination of instruction once again suggests that the conflict over type of instruction is not as important as the need for students to have multiple instructional experiences in the learning of vocabulary. Successes in all of the above areas increase the likelihood that students will comprehend text successfully.

Comprehension

Bondanza, Kelly, and Treewater (1998), suggested that in its simplest form, reading comprehension is the gaining of meaning from text. When children have mastered all of the other
areas defined by the National Reading Panel they can successfully gain meaning from text. Gaps in any of those areas can impede this ability. Keene and Zimmerman (1987) suggest that basic comprehension skills include the ability to understand cause and effect, compare and contrast, identify story structure, identify sequence of events, note details, understand the author’s viewpoint, make generalizations, make inferences, make judgments, and predict outcomes. Further, Schmitt (1986) suggested that strategies for good comprehension fall under three broad categories: planning, monitoring and revising. Several clear ways to aid students in achieving high levels of comprehension have been defined by research.

Concept-Oriented Reading Instruction (CORI) has been researched fairly extensively. CORI focuses on developing reading strategies within content areas (e.g. Social Studies, Science). The framework emphasizes students’ autonomy and engagement and has multiple group formats for instruction. In a study conducted by Guthrie, J. Coddington, Klauda, Wigfield, & Barbosa, P. (2009), with low and high achieving fifth graders, all students exposed in the CORI approach, scored higher on posttest measures of word recognition speed, reading comprehension on the Gates-MacGinitie Reading Test. Wigfield, Guthrie, Perincevich, et.al. (2008), conducted a study to identify whether CORI (which contains a motivational component), just cognitive strategy instruction or traditional instruction would have a differential effect for fourth graders in reading comprehension, strategy use and engagement. Students who were involved in the CORI approach had significantly better scores in the identified areas than any of the other groups. When the engagement (motivational) variable was controlled for, the scores were not significantly different. This suggests that when students are motivated and involved reading ability increases.

Another instructional framework Collaborative Strategic Reading (CSR) has also been researched. This framework teaches specific strategies to use when reading any text. In a study conducted by Klingner, Vaughn & Schumm (1998) fourth graders at varied reading levels were exposed to CSR. Students in the CSR group significantly outperformed those in the control group on reading comprehension. Klingner, et (1998) also conducted a study where CSR was implemented in conjunction with other research-based reading strategies (writing process approach, class wide peer tutoring, making words) for elementary students with low learning abilities. The results also confirmed that use of CSR has resulted in significant improvement in reading comprehension and vocabulary for these elementary students.

Reciprocal teaching, an instructional activity, is often used to aid students in learning how to comprehend text. Paclinsar (1986) describes the concept of reciprocal teaching as an instructional activity that takes place as a dialogue between teachers and students or students and students about segments of text. Taylor and Frye (1992) conducted a study with fifth and sixth graders that had average or above average reading ability. Four comparison groups and four experimental groups were defined (four engaged in reciprocal teaching and four received typical classroom instruction). All groups using reciprocal teaching (except average sixth grades) scored significantly higher than the control on a summarizing task. Average fifth graders scored significantly higher than the comparison group on short answer scores. Further, in a study conducted by Johnson-Glenberg (2000) with third and fourth graders, three types of intervention were used: a visualizing/verbalizing program, reciprocal teaching and regular classroom instruction. Results identified students that received reciprocal teaching instruction performed significantly better on pretest to posttest scores in predictions, question generation, recall, open-ended questions, self-reported strategy use and listening recall. There is strong evidence that
teaching students skills and strategies for comprehension whether in context or not increases their ability as defined on multiple measures.

In conclusion, much research had been conducted in the five areas of reading defined by the National Reading Panel. Though there continues to be some conflict as to the most successful way to teach reading to students, one thing is clear, current research supports a “packaging” of different types of instruction based upon student need.

Math
defined on multiple measures.

Math calculation

Sutton and Kruegera (2002), suggest that many of the skills needed for reading, such as prediction, synthesis, inference making, question asking, and the drawing of conclusions are also necessary for math. The National Mathematics Advisory Panel (2008) stated that students in the United States, in comparison with those from other countries, are unable to demonstrate a variety of math skills. Research suggests that students who can solve math facts quickly and accurately can complete higher order math problems more successfully (Skinner, Fletch, & Hennington, 1996). As with many areas of reading, there is conflict about whether math fluency can be better attained using problem solving with minimal guidance approach (much like the implicit instruction discussed in reading) or whether explicit instruction in skills and strategies are more successful.

Proponents of the minimal guidance approach (e.g. inquiry approach, problem based learning ) suggests that if students, in small groups, are given essential information to solve a problem and left to solve it then individual prior knowledge and learning styles will come into play, and a solution can be found (Bruner, 1961; Steffe & Gale, 1995). This instructional approach to teaching math is designed for students to use their own skills with no explicit instruction from the teacher and is said to increase students’ deeper level of understanding of math.

In several studies, with elementary students, comparing these two types of instruction in science results suggest that students perform significantly better with explicit instruction (Klahr & Nigam, 2004; Moreno, 2004). Furthermore, research has suggested this type of instruction may have negative consequences for students, leading to frustration and incorrect knowledge (Brown & Campione, 1994). Perhaps the key here is the novice condition children are in when learning basic skills and strategies. Kayluga and Ayres (2003) suggest that a person in a novice condition has only enough memory space to include basic facts, whereas; once practice occurs and the information gets stored in long term memory, we are then able to solve problems with it (Gagne, 1982; Hasselbring, Goin, & Bransford, 1987;Pellegrino & Goldman, 1987).

In 2008, the National Mathematics Advisory Panel Report found that explicit instruction was primarily effective for computation (i.e., basic math operations), but not as effective for higher order problem solving. Kirschner, et.al, (2006), suggest that direct instruction must precede application. Further, repeat and practice of skills, corrective feedback, and reinforcement, have all been shown to increase fact fluency (McCallum et al. 2004; Skinner et al. 1989; Skinner and Smith1992). Shapiro (2004) suggests that the development of fluency with basic facts may increase students’ ability to learn, develop, and/or apply advanced mathematics
skills and concepts. Given these viewpoints there is support for the idea that some type of explicit instruction, in the early stages of math learning, is imperative for further success.

Poncy, McCallum and Schmitt (2010), conducted a study comparing the above viewpoints. The goal of the study was to increase fact fluency in a general education class of second graders. The three conditions that were tested were: (1) cover, compare, and contrast (CCC), (2) Facts that Last (FTL) and (3) regular classroom instruction. CCC is an explicit approach with FTL being implicit. Students in the CCC group had a significant increase in fact fluency. There was no significant difference in the other groups. Two months later the increase had continued for the CCC group. Prior to this, using the CCC method Skinner, Turco, Beatty, and Rasavage (1989) taught children multiplication math facts. In other studies using CCC conducted with second graders (Grafman & Cates with a modeling component) and with fifth graders (Lee & Tingstrom 1994) results showed a significant increase in digits correct per minute (DCPM). Researchers investigating explicit timing have found that such procedures can enhance math fluency (Codding et al., 2007; Rhymer, Henington, Skinner, & Looby, 1999; Rhymer, Skinner, Henington, D’Reaux, & Sims, 1998; Van Houten & Thompson, 1976). Another study used the Detect, Practice, and Repair (DPR) approach, where both explicit timing and CCC were combined. This study was conducted by Poncy, (2010) with a group of third graders. On average, students increased from an average of 20.9 DCM in baseline phase to 33.3 and 32.9 DCM during the intervention and maintenance phases, respectively. The 11 intervention sessions were conducted over 11 days and were estimated to take approximately 12 min per day.

There are several research based class wide peer tutoring models, including Classroom Wide Peer Tutoring (CWPT; Delquadri et al. 1983), Total Class Peer Tutoring (TCPT; Lo and Cartledge 2004), and Peer Assisted Learning Strategies (PALS; Fuchs et al. 1997). Generally peer tutoring models include: instruction of the students in procedures, pairing of students in a structured whole class task, and some type of reinforcement base. During the tutoring the teacher closely monitors each pair of students. Hawkins, Musti-Rao, Hughes et al. (2009) conducted a study assessing the effects of class wide peer tutoring in math, which produced positive results. This study was conducted with fifth graders in attempt to increase multiplication facts. The reinforcement system was a randomized pair contingency rather than individual (as is often the case in peer tutoring). Students demonstrated increased multiplication fact fluency across three sets of problems.

Technology software is often used as support materials for math instruction. In a study conducted by Miller and Robinson (2011) with 634 ten to eleven year olds the effects of a commercial computer game were noted. The study was designed to assess mental computations skills and self concept. The games were used for 20 minutes a day for nine weeks. Both the control and experimental group made gains in speed and accuracy, however; the experimental group had 50% greater gains in speed and twice the gains in accuracy than the control group. In a prior study conducted by the same researchers using the same age children but with a computer program called COTS, comparison groups showed only half of the gains in accuracy or speed of calculation in comparison to the experimental group. However, this study had a very small sample size thus the replication. In general, studies suggest that technology as a support to regular curriculum is useful.

Math fluency is clearly a pre-requisite to the ability to problem solve. In general, research supports a more explicit type of instruction for the learning of skills and strategies. Once these skills become automated children then have them stored in their long term memory for retrieval in terms of higher level thinking skills.
Problem-solving

Reys, Lindquist, Lambdin, Smith, & Suydam (2001), suggest that problem solving is a foundation for proficiency in math. Further, Burns (2000) suggested that it is imperative that elementary math curriculum help children become problem-solvers. Research shows that there is a discrepancy between children’s ability to solve word problems not because they have poor computation or reading skills, but because they don’t know which operations to choose (Burns, 2000). This statement suggests that strategy instruction is very important in performing problem solving tasks. Again, there is disagreement as to whether explicit instruction is a more successful way to teach problem solving than the unguided inquiry approach. Mayer (2004) suggests that the “debate about discovery has been replayed many times in education but each time, the evidence has favored a guided approach to learning” (p. 18). Aulls (2002), observed a number of teachers as they implemented “unguided” activities in their classrooms. As students failed to learn, he observed a large amount of scaffolding by teachers. Further, his observations conclude that students that were successful in problem solving tasks were aided by teachers modeling procedures, paraphrasing information, having them use notes and helping with collaborative dialogue. This then appears to support the idea that explicit instruction must occur within the context of the unguided approach. Marcucci (1980), examined the findings of 33 research studies in elementary school classrooms since 1950. Marcucci found that teaching methods that emphasized general problem solving strategies and skills were the most effective. Polya (1957) proposed a four-phase model for problem solving: (1) understand the problem, (2) devise a plan, (3) carry out the plan, and (4) look back to examine the solution. Although simplistic it offers teachers a basic framework to help students organize the task of problem solving. In a study conducted by Leh (2010) with third graders, groups of students were given computer mediated or teacher mediated instruction. Both groups were taught strategies that guided them to identify the problem type, and map the problem features using diagrams. Further, both conditions used diagrams, worked examples, visual representation and modeling (all considered in the literature to be important strategies (Ainsworth 1999; Schnotz & Bannert 2003; Gick & Holyoak 1983; Bransford & Schwartz 1999). Results suggest that only strategy instruction was effective in increasing and maintaining word problem solving skills. In addition, strategy instruction along with collaborative groups has been shown to be extremely effective. Student-student discussion, one component of small collaborative groups resulted in significant growth in problem solving abilities (Noddings 1982; Noddings, Gilbert- Macmillan, & Leitz 1983). Slavin & Lake (2007), conducted a synthesis of effective programs for elementary schools and suggest that the following methods increased student proficiency in problem solving: (1) class peer tutoring (paired learning), (2) Peer assisted learning strategies (PALS) (structured paired learning), (3) power teaching (cooperative group where students work in 4 member teams). Clearly, research supports the use of strategy instruction and cooperative groups for elementary students increased ability to solve word problems. It is also clear that technology plays an important role in supporting math learning but not necessarily in place of it. In a summary conducted by Cheng & Slavin (2011), it is suggested that supplemental computer assisted technology has the largest effect on student math success. Computer managed learning and more comprehensive, full curricular models had much small effects.

In conclusion, there has been much research in the area of math computation for elementary students, but less so for problem solving. Perhaps the emphasis of skill development is more clearly defined at the computation level, however, it would appear that more research in
this area would be helpful for teachers attempting to pair skill development with problem solving strategies.
References


